Meeting Product Performance Requirements Through Heat Treatment and Annealing

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A component or assembly may satisfy all the dimensional requirements for its intended use and still not perform as needed. Unless the material properties match the demands of the application, the part will fall short of its performance goals. Even specifying the correct grade and alloy of the component material may not be enough to ensure the part performs as intended.

Manufacturing processes, including machining, plating, and even how the raw material is initially formed, can have an adverse effect on the desired material properties. Heat treatment, annealing, and stress relieving operations performed by Electro-Spec ensure the parts will meet proper specifications for strength, ductility and durability. Typical parts treated are contacts and crimp tubes, with acceptable part size up to 12″ in width.

Crucial First Steps – Identifying the Process and Preparing the Material

Achieving the desired component specifications will be strongly dependent upon selecting the correct treatment process for the material, alloy, and intended mechanical properties (hardness, ductility, machinability, etc.). Electro-Spec has experience with a wide variety of treatment processes for copper and nickel alloys. These include, but are not limited to, military, aerospace, automotive and medical processing specifications.

Successful execution of any treatment process starts with proper cleaning of material. Residual dirt, oil, and other contaminates can adversely affect the components during the elevated temperatures seen in most treatment processes. Electro-Spec employs vacuum vapor degreasing to ensure part cleanliness and can also meet the additional preparation requirements identified in many treatment specifications.

The final material performance requirements will drive the selection of the treatment process to be used. Electro-Spec can process materials to strengthen or harden them through heat treatment, soften or increase ductility through annealing, or improve durability through stress relief. These processes are described in more detail below. Manufacturing processes, including machining, plating, and even how the raw material is initially formed, can have an adverse effect on the desired material properties. Heat treatment, annealing, and stress relieving operations performed by Electro-Spec ensure the parts will meet proper specifications for strength, ductility and durability. Typical parts treated are contacts and crimp tubes, with acceptable part size up to 12″ in width.

Heat Treating – Enhancing a Component's Material Properties

Heat treating methods vary tremendously depending upon the material to be processed. However, the basic steps are common to all: heating the material at a specified rate; maintaining the material temperature for a set time period (ranging from 30 minutes to a few hours); and cooling, done gradually or rapidly, in a certain medium (typically in a pure atmosphere of a specific gas for example). Electro-Spec can process parts up to 1,000°F in air, nitrogen, or nitrogen-hydrogen environments.

Heat treating can be used to harden a specific area of a part, the outer surface (sometimes called "case-hardening), or the entire part (through-hardening). Variations in the heating and cooling regimens are used to achieve the different effects on the part. Subtle changes in the processing temperature, aging period, or cooling methodology will dramatically affect the final hardness, toughness, ductility, and stability of the final product. Electro-Spec provides through-hardening of parts.

Heat treatment can be an economical way to bring the mechanical properties of a low cost material up to the level of a sophisticated alloy. Often a part whose final application requires a hardened wear surface is made from a softer, easier to machine material. Heat treatment is employed to increase hardness to meet performance requirements. This way, less expensive materials can be rapidly machined then processed to achieve their required material properties.

The alternative, starting with a hardened material, is often not economical due to the price of the raw material and the difficulty in machining. Electro-Spec has successfully hardened carbon and stainless steels, spring steel, and high-performance alloys like Kovar and Invar.

Annealing – Improving the Ductility of Raw Material or a Finished Part

Annealing can be used to increase the formability and ductility of a variety of materials. Raw material that is hardened through its manufacturing processes (like rolling or drawing) can be softened to allow it to be bent or formed more easily and without cracking. Parts that have been formed by fabrication processes like stamping or bending can be annealed to increase their flexibility and durability for their final application. In addition to a variety of steel alloys, Electro-Spec can also anneal copper and copper alloys as common as brass and as specialized as beryllium copper.

As with heat treating, there are many different annealing processes tailored to achieve different material properties in specific materials. However, annealing can be categorized into three broad areas: Full Anneal, Normalizing, and Process Anneal.

A full anneal is only used when the most complete softening of a material is required. It is usually performed on raw material before further manufacturing processes, but finished parts can be fully annealed as well. It is a time consuming process that can require a long, gradual cooling procedure. It can not only increase the ductility, but it also lowers the yield and tensile strength of the material. Fully annealed material can be significantly easier to form and machine compared to the original raw material.

Normalizing is typically performed on ferrous materials to improve machinability and increase material stability. It is not as involved as full annealing, but it still results in a tougher, more ductile material.

Process annealing is an intermediate step performed during the fabrication of a part. It is used to restore some of the ductility that is lost during an earlier processing step such as stamping or bending. This is done to ensure the part will not crack or fail during subsequent fabricating steps. Process annealing can improve part yields and final part quality.

Stress Relieving – Improving the Durability of the Finished Part

Stress relieving is much like annealing, but the part properties are not affected as significantly as with a full anneal. Stress relieving is usually done to reduce localized stresses resulting from work hardening or machining processes. It can toughen the part by eliminating stress concentration points that could lead to failure if the part is subjected to vibration or alternating loads. Stress relieving processes are usually done at a lower temperature and the cooling time is shorter as well. Electro-Spec can stress relieve a variety of steel and copper alloys.

Pitfalls of Heat Treating and Annealing – And How to Avoid Them

Although immensely beneficial in improving part performance, all of the processes described above have the potential to adversely affect part quality and performance. Improper application of treatment methods can result in embrittlement, corrosion, scaling, or warpage. Careful selection and application of treatment processes must be done in order to achieve the desired results.

Processing of material in controlled atmospheres is one way to ensure that surface contamination is avoided. Treatment of steel and copper alloys often must be performed under a blanket of nitrogen to avoid oxidation. Typically referred to as "heat scale," surface contamination and oxidation creates a layer that is sometimes impervious to traditional cleaners and acids, and can lead to blistering and delamination of the plating. Some processes require a nitrogen-hydrogen mix to more effectively dilute and capture oxygen contamination and to prevent heat scale. Electro-Spec has the equipment, experience, and knowledge to employ the correct cleaning procedures and controlled atmosphere to achieve the required part finish that is ideal for plating.

Even under the best controlled conditions, some contamination cannot be avoided. Electro-Spec can address hydrogen embrittlement that can result from some treatment processes through the application of procedures defined in AMS QQ-N-290 specifications.

An experienced blacksmith can judge the temper of the material by its color, but there is no place for subjective judgments in the evaluation and execution of treatment processes performed at Electro-Spec. Processing equipment and measurement tools are calibrated to nationally recognized standards to ensure that part requirements can be achieved and confirmed. Statistical quality control procedures are employed to monitor treatment processes and identify and correct deviations before they can affect part quality. Processing data can be made available through web-based applications, so customers can monitor and confirm the treatment is performed as specified.